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MERCURY AND CYANIDE USED AS INDICATORS OF SEDIMENT TRANSPORT IN EPHEMERAL WASHES AT THE TECHATTICUP MINE AND MILL SITE, NELSON, NEVADA (USA)

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ABSTRACT

Mercury (Hg) and cyanide (CN⁻) are used as indicators of aquatic transport down gradient in ephemeral washes. The pattern of transport for Hg and CN⁻ should mimic other metals (As, Cu, Cr, Pb, Ni, Ba) found in the soils. Hg and CN⁻ were chosen to illustrate transport in surface soils because Hg and CN⁻ are utilized in the milling process and Hg is available from the local geology. Stamp mills that utilize Hg and CN⁻ flotation concentrate naturally occurring metals as byproducts. Soil samples collected from a wash system bisecting the mine waste site contained metal concentrations significantly above background levels. Mercury and cyanide concentrations showed dissimilar distribution patterns throughout the wash system with Hg and CN⁻ 30- and 95- times greater than background concentrations. Concentrations of various heavy metals corresponded well with the concentrations of mercury and cyanide throughout the wash system validating the use of specific analytes as tracers of transport of contaminated soils.

Keywords: Nelson, Nevada, Mining, Historic, Soil, Contamination, Metals

1. INTRODUCTION

Migration of contaminated slurry waste from abandoned mine and mill sites in Southern Nevada has the potential to impact the surrounding environment from storm events, wind, and construction activities. The Techatticup Mine was chosen for this study based on its location up stream from Lake Mohave, a major water source for the Southwestern United States (Figure 1). The area where Techatticup Mine is located is arid, with less than 3 inches of precipitation per year, and with the majority of the precipitation occurring in a few major storm events.

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We investigated this mine site to assess the movement of heavy metals and CN- and to determine the distance contaminated soils have moved and their mechanism of transport. The Techatticup Mine is situated at the top of a small basin that is bisected by a major wash system. This major wash system (Techatticup Wash) originates 4 miles above the mine and terminates at Lake Mojave, formerly the Colorado River. The Techatticup Wash is aligned east to west and converges with two major wash systems 2 miles below the mine. With the bisecting of the mine by the wash it is conceivable that contaminated soils have migrated down slope to Lake Mojave (see figure 1).

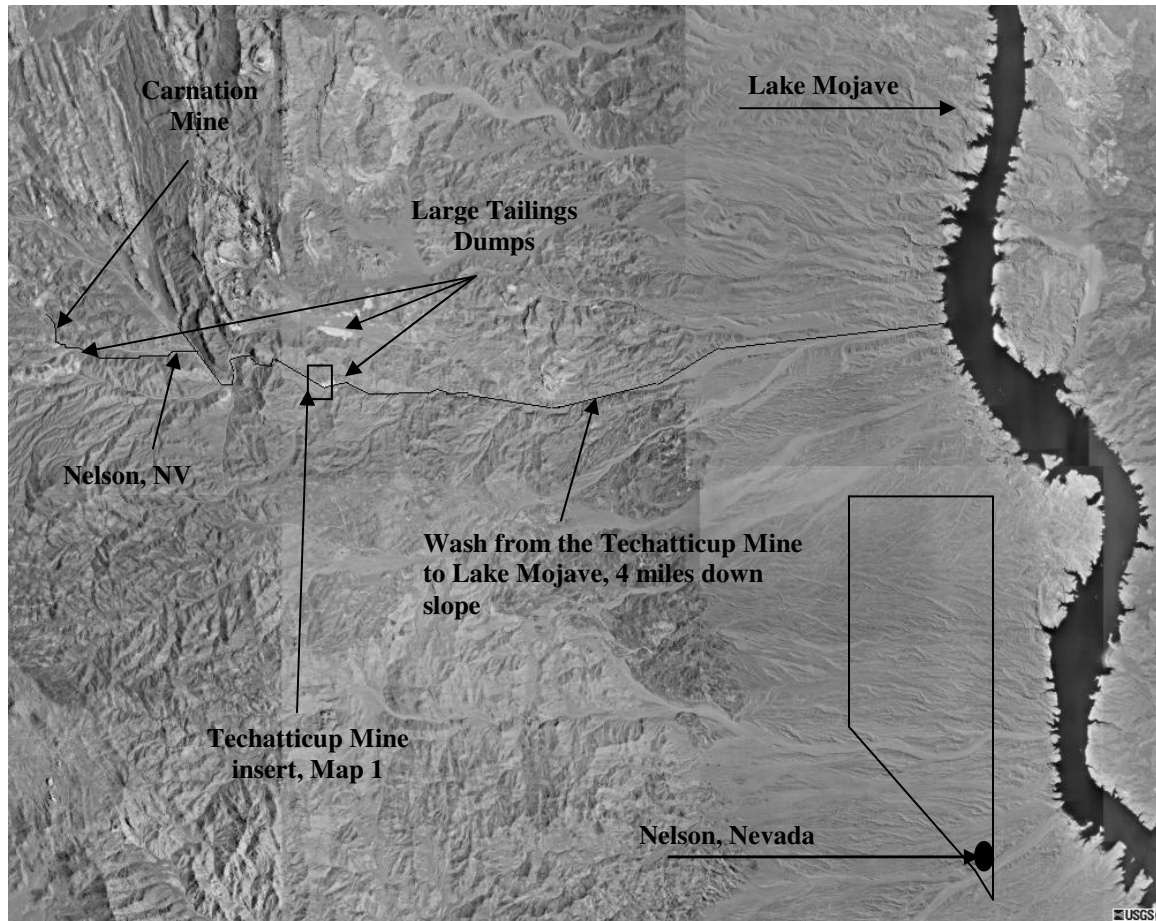


Figure 1. Aerial of Nelson, Nevada with Lake Mojave to the east, 6 miles
Source: USGS Black and White Aerial, 1994 (Lat: 35.69149; Lon: -114.76357; Approx Scale: 1:24,000)

Historical mine sites have created unforeseen pollution problems, particularly metal contaminated soils, with the potential to impact a wider environment through transport in desert washes. Many historical mine sites located in relatively dry areas have not received much scientific attention because it is presumed that without precipitation or a high water table, soils contaminated with the byproducts of mining will be relatively immobile. However, there is a possibility of contaminants migration via erosion (wind or

water) and the occasional 500 year storm events, such as the 1974 storm that produced a reported wall of water more than 3 meters in height down the main channel of Eldorado Canyon (Martin et al, 1974; Sims and Bottenberg, 2007).

In Southern Nevada alone, there are more than 1000 abandoned mines (Sims and Bottenberg, 2008). Many of these mines are solely minor adits or shafts with no real significant land alteration or milling facilities. However, in areas like Nelson, Nevada, there were several mines that operated milling facilities for their mining activities and those of surrounding mines. Over the last half century many of these mines have gone unchecked and have been largely forgotten. Generally, many of these sites are located in desert washes, are in relatively dry areas, and are within short distances of permanent water sources such as the Colorado River.

Over time, mining activities resulted in large amounts of contaminated soils being dumped adjacent to (and more likely into) nearby desert washes. Movement of this waste material has been of minor concern given that migration into ground or surface waters requires a climate with meaningful amounts of precipitation or a high water table. Nonetheless, storm events routinely generate flow in ephemeral washes during monsoon season, such as in the previously discussed 1974 storm event.

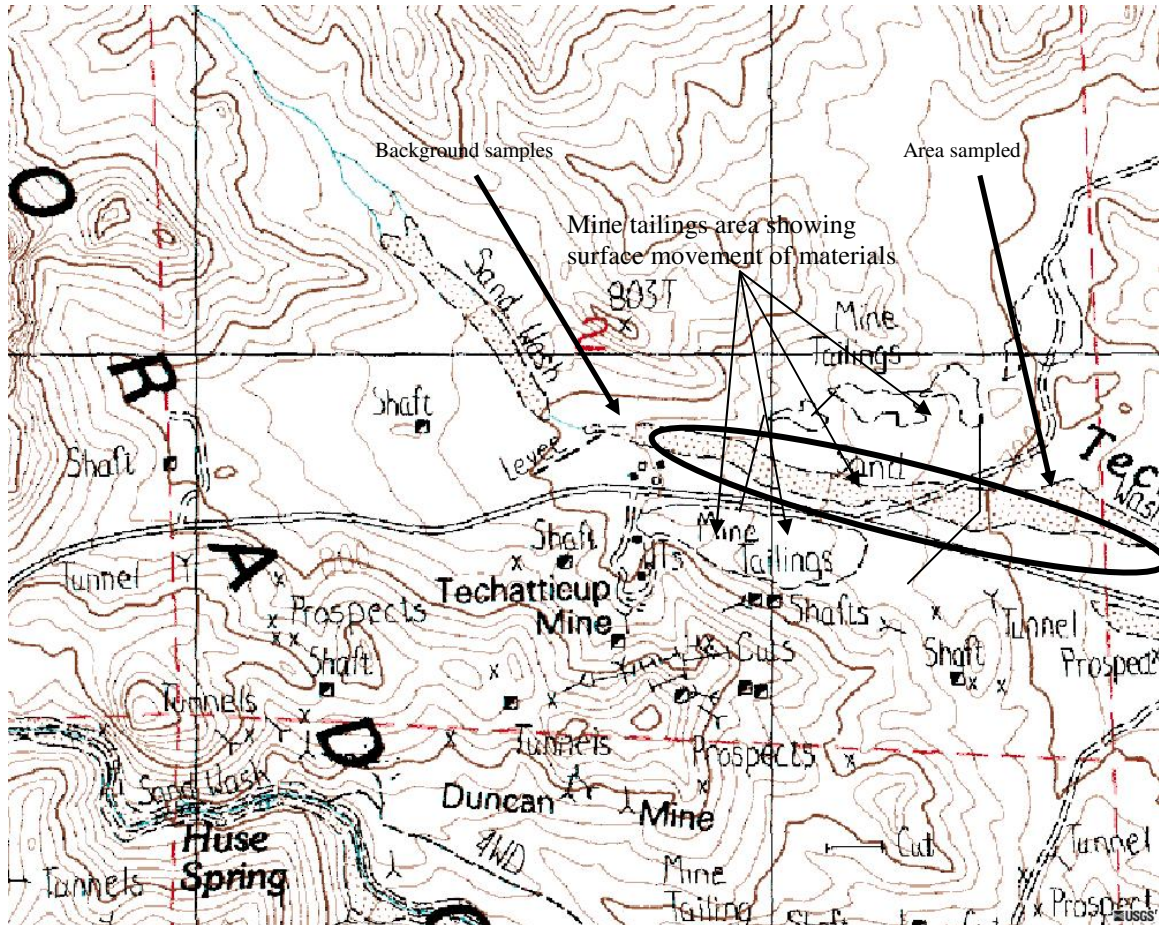
Operations of the Techatticup Mine were conducted in the absence of any environmental regulations governing the transport and disposal of waste products. Wastes generated between 1857 and the 1930s at the mine were dumped in large settling ponds adjacent to the mine property (see map 1). The refining of precious metals from aggregate ore began by processing the material through a stamp mill to reduce the rock to a fine powder that was then slurried and passed through a flotation mill (Bunyak, 2000). This process produced large amounts of waste slurry containing high levels of naturally occurring metals as well as additives used in the process, such as CN⁻.

2. PREVIOUS STUDIES

Fluvial migration of metal contaminated soil material appears to be the focus of much research. Mining sites located in areas with high precipitation appear to be major sources of migration, whereas the movement of contaminated materials in surface waters via streams and rivers is also an important means of transport. Materials transported in surface waters is important, however, runoff and surface water transport are only two means by which contaminated soils can be mobilized.

Today many abandoned mines appear as they did when the last operations ended over 40 years ago. Specifically, they have heavily contaminated soils, tailings, and overburden containing waste materials and chemicals that were used in the extraction process (Hall-Patton, 2003). Traditionally, materials from mining operations were discharged into the surrounding environments adjacent to mines. Metals concentrations in soils surrounding areas of mining operation are commonly found at elevated levels. This is directly related to mining operations, and, mining wastes transport is directly linked to rivers and streams that cut through many of the mining sites (Macklin et al., 2001, 2006, 1997; Rowan et al.,

1995). Pollution in the wider area surrounding a mine site is correlated with streams where heavy metals from past mining activities were released over a long period of time (Yim, 1976). Much of the contamination of the wider areas is a result of overland flow to



Topographic Map 1. Nelson, NV, 7.5" USGS, 7.5 minute, 1984

local streams and rivers. The transport of these materials to local rivers and streams has been the focal point of much research (Macklin et al., 2001, 2006, 1997; Rowan et al., 1995; Yim, 1976).

Pollution from mines can occur not only from water transport but from mine seepage, soil loss by overland flow, and flow affecting tailings improperly disposed of in rivers and streams. Over the years, many abandoned mines have not been remediated, and the waste materials have found been transported into the wider environment, sometimes great distances from the source material (Davis and White, 1981; Camm et al., 2003). Researchers have focused on acid mine drainage and sediment transport in wet climates of northern California, Colorado, Nevada and globally. Each of these states has abundant precipitation which provides optimal conditions for the movement of materials (Rampe and Runnells, 1989; Van Bueren, 2004; James, 1991).

The extent of contamination goes beyond that of just soils and waters, to include biological impacts of mining waste extending into the health of humans and animals through contaminated food supplies (Cloutier et al., 1985). The location of mining facilities in relation to population and farming has a negative impact on the overall environment through the transport of materials by wind and water, and surface runoff of contaminated soils and waste (Cloutier et al., 1985). Not surprisingly, mining activity sparked population growth in nearby towns and cities that supplied the labor to mines and milling facilities (Cloutier et al., 1985). Today, many of these towns and cities remain larger in population whereas nearby mining and milling sites have been abandoned and left unattended for decades.

3. MATERIALS AND METHODS

Nineteen soil samples were collected from a wash that intersects the Techatticup Mine site, continuing down gradient approximately 6 miles to Lake Mojave (see Figure 1). The sampling strategy was designed to assess migration of contaminants from the mine tailings. This included collection of samples from 60m above the point where tailings were eroding into the wash at location 0 to 400m below where tailings were eroding into the wash system. Sampling did not extend beyond 400 meters down gradient from the milling facility because this first phase site investigation was to evaluate the potential for migration off the immediate mill and mine site. Samples were collected from the surface of wash sediments and did not exceed 5 cm in depth. Only one sample was collected per location and all samples were single point-center collection from the wash that bisected the mine waste area.

Background concentrations for the eight contaminants of interest were determined by collecting three samples above the mine in the wash that cuts through the site, and these are presented in Table 1.

Table 1. Background levels of contaminants in Nelson, Nevada

Contaminant	mg kg⁻¹
Arsenic	11
Copper	22
Chromium	19
Barium	55
Lead	12
Nickel	12
Mercury	0.02
Cyanide	<0.01

Samples collected for background analyses were collected at -20, -40 and -60 meters above location 0, a source of tailings eroding from the Techatticup Mine waste area.

Background sample values were averaged over the three collected since the concentrations for target analytes had less than 1 relative standard deviation (RSD).

The samples were air-dried and ground before sieving them through a 2 mm nylon sieve. United State Environmental Protection Agency (USEPA) methodologies SW-846 were utilized during the analysis portion of this research. Metals were processed with method 3050B for total metals (As, Cu, Cr, Pb, Ni and Ba). Briefly, this included digesting 1.0g of sample with 6 ml of concentrated aqua regia acid heated to 95°C for two hours. This was followed by a cooling of the sample and then adding 3 ml of 30% H₂O₂ to each sample and reheating to 95°C for an additional 30 minutes. Each sample was filtered through Whatman 541 (2µm) filter paper and diluted to 50 ml prior to being analyzed by inductively coupled plasma-optical emission spectrometry (ICP-OES).

For Hg analysis, the samples were digested according to USEPA method 7471. This involved adding about 0.2 g sample mass to 5 ml of reagent water and 5 ml of aqua regia, heated for 2 minutes in a 95°C water bath, then adding 50 ml of double deionized reagent water and 15 ml of KMnO₄. After 30 minutes the samples were removed from the water bath and, once cooled, 6 ml of sodium chloride-hydroxylamine sulfate was added to reduce the KMnO₄. The digestates were analyzed on a cold vapor atomic adsorption (CVAA) instrument.

Samples analyzed for CN⁻ were per USEPA method 9010; weighing 1.0 gram of sample into a 50 ml distillation tube with 50 milliliters of 10% by volume NaOH; samples were placed in distillation tubes under vacuum with the addition of 10 milliliters 50% by volume H₂SO₄; samples were heated to a boil for 90 minutes; after distillation samples were purged through 50 milliliters 10% by volume NaOH solution and analyzed colorimetrically.

For quality assurance/control, each batch included replicated samples, reagent blanks and certified reference materials (RTC Corporation, Laramie, Wyoming). The variation, as measured by % relative standard (1σ) for certified reference material and duplicated samples was <10%. The recovery of metals and CN⁻ was within ±10% of the certified values.

4. RESULTS

Mercury and CN⁻ concentrations in surface sediments below the mine clearly show the presence of mine contaminants down gradient (Figure 2). At 60 meters above the mine, concentrations were at background levels for metals with a non-detectable concentration of cyanide (Table 1). Samples collected from the tailings eroding into the wash had higher metal (As, Cu, Cr, Pb and Ba) concentrations compared to background concentrations (see figure 3). Cyanide concentrations varied between 0.32 and 0.95 mg kg⁻¹ from the point where tailings eroded into the wash and 400 meters down gradient from the eroding tailings. Data show mercury concentrations increased from 0.10 mg kg⁻¹ in the wash where tailings are breached to 0.29 mg kg⁻¹ at 220 meters and 0.05 mg kg⁻¹ some 400 meters from the breach of tailings.

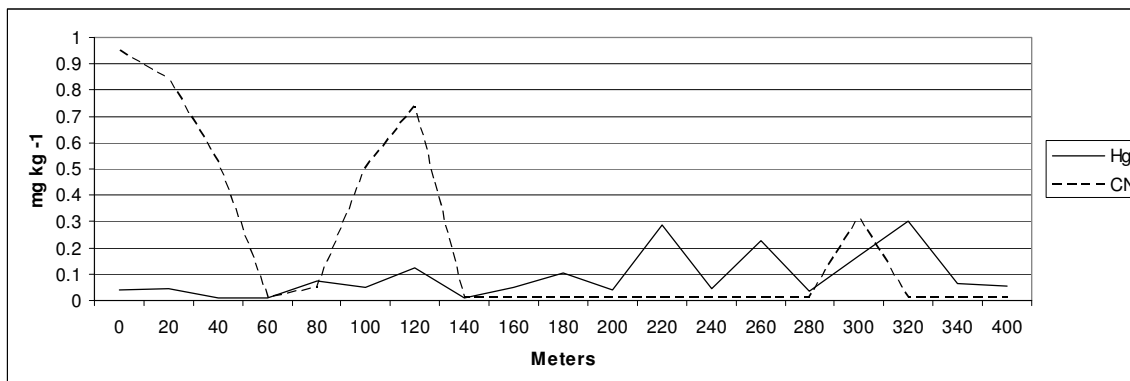


Figure 2. Hg and Total CN- as a Function of Distance at Techatticup Mine

Samples analyzed for mercury show higher concentrations at 120, 160, 180, 220, 260, 300, 320 and 340 meters down gradient of tailings with concentrations of Hg ranging between 0.05 and 0.29 mg kg⁻¹. At periodic intervals, elevated Hg and CN⁻ concentrations indicate material containing Hg and CN⁻ has moved down gradient from the tailing breach at the Techatticup Mine and mill site.

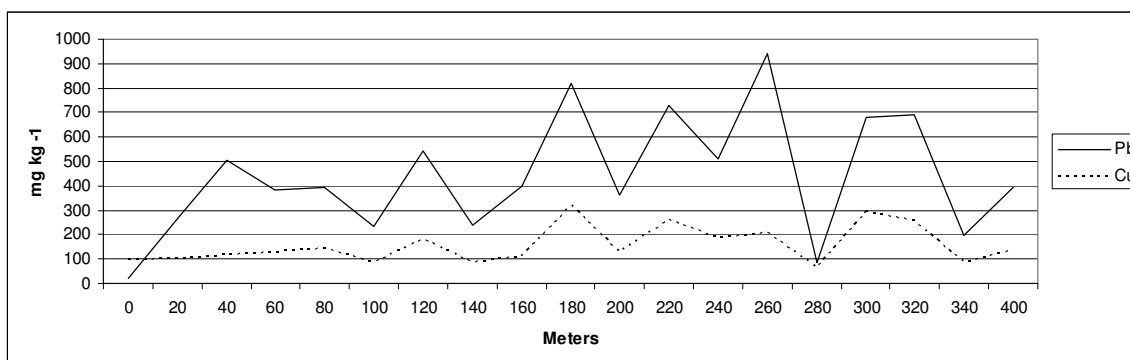


Figure 3. Metal Distribution in the Techatticup Mine Wash

5. DISCUSSION

Metal concentrations for Pb, Cu, Cr, and Ni indicate specific locations of elevated concentrations within the wash system (Techatticup wash) that bisects the Techatticup mine and mill. Metal concentrations within the 460 meter linear sampling of the Techatticup wash ranged between 20 and 944 mg kg⁻¹ for Pb, 28 and 68 mg kg⁻¹ for Cr, 66 and 260 mg kg⁻¹ for Cu, 24 and 120 mg kg⁻¹ for Ni. Cyanide and Hg levels were not detected above the mine while soil samples at the tailing breach contained 0.95 mg kg⁻¹

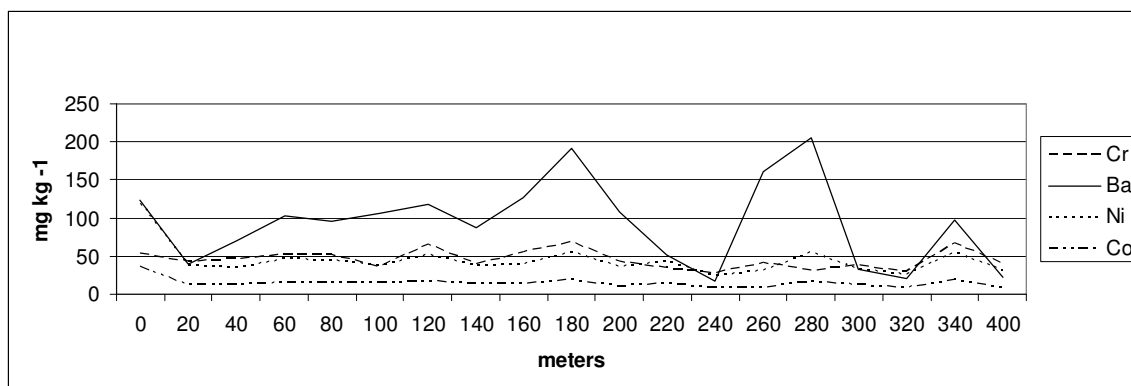


Figure 4. Metal Distribution in the Techatticup Mine Wash

CN⁻ and 0.05 mg kg⁻¹ Hg. Soil samples between 120 and 400 meters down gradient from the breach contained 0.13 to 0.32 mg kg⁻¹ Hg and <0.01 to 0.74 mg kg⁻¹ CN⁻ indicating transport of sediments. It was illustrated in Figure 3 that metals of interest (Pb, Cr, Cu, Ni) are following a similar pattern of distribution as Hg and CN⁻ illustrate in Figure 2 with constituents of interest following a similar distribution in soils.

6. CONCLUSION

It is plausible that all eight metals are being transported in similar patterns of “hot spots” as Hg and CN⁻ illustrated in Figures 2 and 3. Tributaries to the wash that bisects the mine could contain additional contamination or clean soils that effectively elevate or dilute the “hot spots”. Movement of soils from wind, groundwater, surface water or minor storm events is not the concern at the Techatticup Mine. Rather, large scale movement of such soils during major storm events is most likely a factor in hot spots below the source. Additional research is necessary to determine the extent of contaminant migration in the form of hot spots that occur below the mine source and to understand their true nature of transport between the mine and Lake Mojave.

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